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THE LESSONS OF THE COLORADO CANYON.\*

BY

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The Colorado Canyon is a superb illustration of the work of erosion in the plateaus of northern Arizona. It was first scientifically described about 50 years ago by Newberry, who clearly announced its normal origin; it was followed through its entire length in boats by Powell, who described many remarkable features in its history; it was thoroughly investigated by Dutton and elaborately illustrated by Holmes, whose report forms Monograph II of the United States Geological Survey; it is now visited by many thousands of tourists annually. There is, however, no general appreciation of the lessons that the canyon teaches. The usual visitor too often hesitates to regard the canyon as the work of ordinary processes, and inclines to attribute its beginning at least to a great fracture in the earth's crust, produced by some "convulsion of nature." This view has the aristocratic merit of antiquity, but no other. True, great fractures of the earth's crust do traverse the plateaus of northern Arizona; but there is no reason to think that they were suddenly produced; they do not appear as gaping fissures; and they all trend about north and south, while the course of the canyon, from east to west, is entirely independent of them. On the other hand, not only the main canyon, but all the numerous side

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\* Abstract of a Lecture delivered before the Society on April 20th, 1909, on the occasion of the presentation of the Cullum Geographical Medal, which was awarded to Professor Davis in March, 1908.

canyons, branching again and again as they are gnawed back into the plateaus, bear every mark of having been gradually worn by the work of streams along their channels, and of weather on their walls. They are larger than most valleys, but in no other significant respect do they differ from the ordinary work of water and weather.

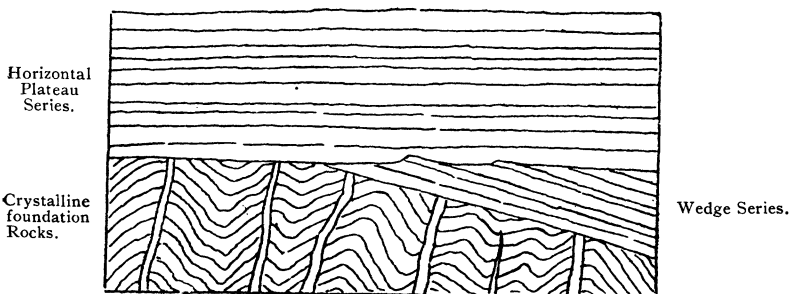
If the visitor is thus persuaded that the canyon is not the result of any sudden process, he may exclaim: "Can the earth be old enough for so enormous a valley to have been worn out by the slow action of ordinary processes!" And any one who sees the hundred miles of canyon length, its nearly a mile of depth, and its five or ten miles of breadth at the plateau level, must at first sympathize with this exclamation. Yet the most emphatic lesson that the canyon teaches is that it is not an old feature of the earth's surface, but a very modern one; that it is does not mark the accomplishment of a great task of earth-sculpture, but only the beginning of such a task; and that in spite of its great dimensions, it is properly described as a young valley. If one would appreciate the dimensions of a really great erosional work, let him imagine the processes by which the canyon has been produced to continue in operation until the main canyon shall slowly wear deeper and deeper, and the side canyons, increasing in length and width, shall consume the entire plateau, hundreds of miles north and south of the river, and thus the whole region shall be reduced to a featureless lowland but little above sea level. When that result is reached, we might well say that a vast work has been accomplished. It is in relation to that completed task that the work thus far accomplished is to be considered only as a beginning, and that the canyon is to be described as a young valley.

But the visitor who at the outset hesitated to regard the canyon as the slow work of normal erosive processes, and who, when converted to this belief, exclaimed that the erosion of such a canyon must have occupied nearly all the ages of the earth's history, will be little disposed to accept the possible realization of so much greater an accomplishment as is demanded in the reduction of the highland to a featureless lowland, little above sea level. He will be inclined to treat such a suggestion as a fantasy of the theorist, hardly worth consideration by the every-day, practical man; and if assured that logical reasoning can lead to no more important conclusion for the understanding of the canyon, he will imagine that the reasoning must be technical and recondite, beyond the understanding of ordinary mortals. It is the correction of these misapprehensions that make a visit to the canyon so repaying; for there better than anywhere else in the explored world is this fantastic suggestion con-

verted into reality, and all on evidence so simple that the ordinary traveller, endowed only with plain eyes and the usual portion of common sense, may appreciate the whole course of reasoning which compels the investigator to treat the canyon as a young valley. The canyon is only the record of the first few pages of a new chapter of earth history, which was not entered upon until seven other chapters, all recorded in or near the canyon, had been successively carried to essential completion.

Manifestly, the erosion of the canyon could not have been begun until after the making of the great plateau in which it is eroded. Let us therefore turn our attention from the canyon to the plateau, and particularly to the structure of the plateau mass, as exhibited in the great natural sections of the canyon walls. Here one may see the records of five of the seven chapters of earth history, and not far away one may study the sixth and seventh, each of which was enormously long as compared to the time required for the erosion of a mere canyon; each of which required the essential completion of a task, compared to which the canyon is only the beginning; truly a very respectable beginning, but nothing more.

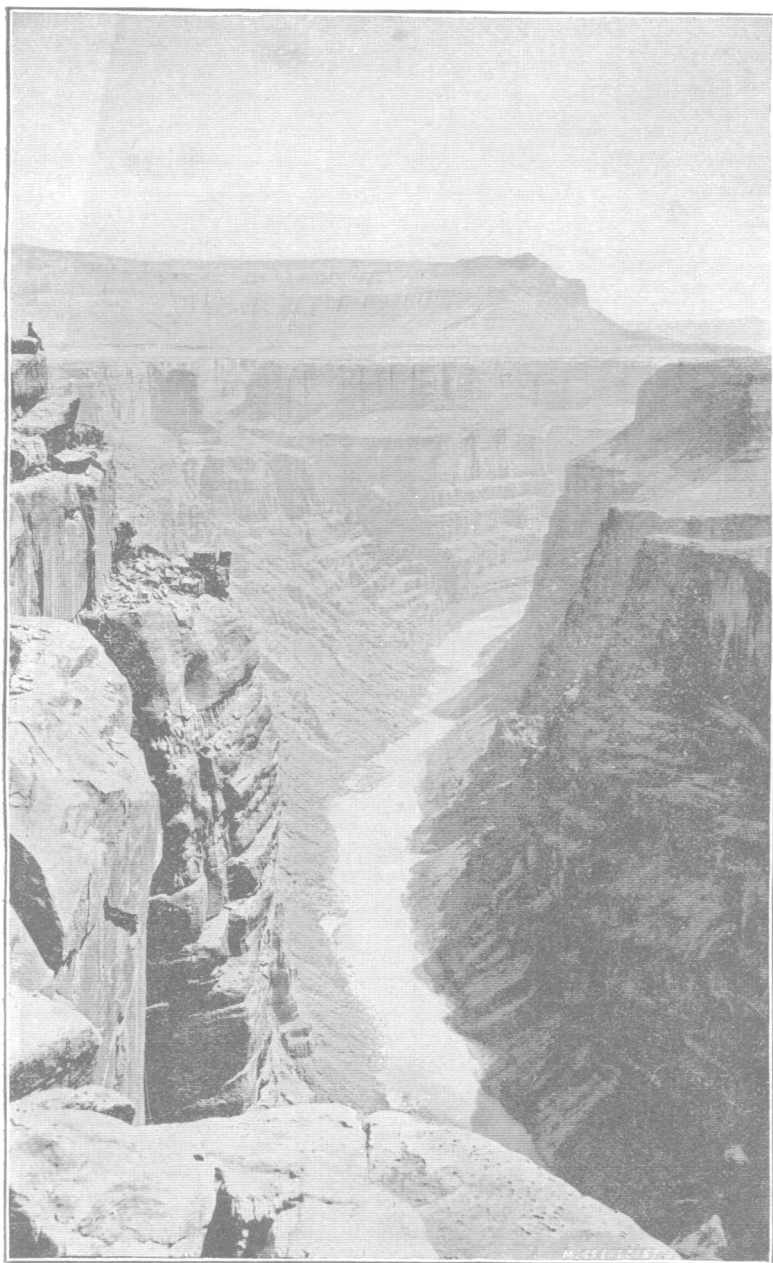
An inspection of the canyon walls shows us that they contain three different series of rocks; an underlying mass of deformed crystalline schists of unknown depth, penetrated by many dikes and veins; an inclined series of stratified rocks, some 11,000 feet thick, lying evenly on a smoothly inclined floor of crystalline rocks; and a horizontal series of stratified rocks, some 4,000 feet thick, lying on a nearly level floor which truncates the two older structures. We may speak of the oldest rocks as the foundation; of the youngest as



the plateau series; and of the intermediate mass as the wedge series, because of its position with respect to the other two. It is the resistance of the fundamental crystallines which determines the narrowness and the steep walls of the "inner chasm" where it is cut

through these deep-lying rocks. It is the horizontal attitude of the plateau series which determines the cliffs, formed by the harder members, to contour around the great promontories between the side canyons, and which determines the whole succession of cliffs and slopes, however irregular they may be in plan, to exhibit almost everywhere the same profile. It is the relative weakness of the wedge series which determines the widening of the canyon in the eastern part of the Kaibab plateau (some twenty miles east of the railroad station on the canyon rim), where these interpolated strata replace the resistant crystallines in the canyon bottom. The making of the crystalline foundation rocks must have involved an enormously long chapter of earth history, because their volume is very great and their accumulation must have required long-continued processes. Moreover, their crystalline texture can be accounted for only by supposing the former presence of a great superincumbent rock mass, so as to bury the parts now seen deep below the then earth's surface and subject them to conditions of great pressure and high temperature, under which alone the crystalline structure of their minerals and the wrinkled arrangement of their foliation can be accounted for. Surely, the production of this great crystalline mass with its superincumbent part must have occupied a long chapter of time. Next follows a chapter of erosion, during which the superincumbent part, of great but unknown altitude, was slowly worn away, grain by grain, to be deposited in the form of stratified rocks somewhere else; for only thus can the foundation, on which the next following wedge series lies, be accounted for. At that time, the now slanting foundation surface must have stood essentially level. The levelness of the foundation surface can be accounted for only by supposing that the former superincumbent part of the crystallines was worn down to a featureless plain; that is, the flat foundation gives us the realization of a great erosional work in the past, similar to the completed erosion of the plateaus in the future, compared to either of which the erosion of the canyon is only a respectable beginning.

It is proper enough for a visitor to the canyon to meet the first suggestion of the complete erosion of the plateaus, north and south, with incredulity; it is perfectly reasonable to doubt that so great an erosional task can be accomplished, as long as one has no direct evidence of the accomplishment of similar tasks. But on the other hand, it would savor of undue conservatism to persist in such incredulity after a good example of the actual accomplishment of such an erosional task, like the buried plains of erosion deep in the canyon



GRAND CANYON OF THE COLORADO.

Looking east from the foot of the Toroweap Valley. Depth at this point, 4,500 feet.

(From THE BULLETIN, Vol. 10, No. 2, illustrating "The Great Walled River," by F. S. Dellenbaugh.)

wall, has been pointed out. The great value of the canyon is, therefore, not only that it shows us the vigorous beginning of a cycle of erosion, recorded in the canyon itself, but also the end of a cycle of erosion, recorded in the structure of the walls.

The even surface of the crystalline foundation, on which the now slanting strata of the wedge series lie, is to be seen in section at various points along the canyon, separated by a score of miles; it is everywhere a very even surface. Hence, before the deposition of the now slanting strata of the wedge series, the surface of the foundation crystallines must have been an extensive plain. Whether the plain was the work of marine abrasion, as the waves of an ancient sea slowly cut away a bordering continent; or whether it was the work of subaërial erosion, which slowly wore down the hills until all the valleys coalesced in a featureless lowland close to sea level, we cannot now decide; but in either case the ancient destructive processes must have been continued through an essentially complete cycle of erosion. That is the main point.

The hearer of this explanation may, however, ask: Is this a geographical or a geological discussion? The question is pertinent; for the consideration of past processes is essentially geological, and it may at first hearing seem out of place in a geographical lecture. Nevertheless, it is really not irrelevant to introduce geological considerations into a geographical lecture, because geography is only the geology of to-day; and we cannot properly appreciate to-day without some understanding of the many geological yesterdays. Conversely, geology is only an integration of a long series of past geographies; and we cannot properly appreciate those yesterdays without a good understanding of what is going on to-day. It has too long been the habit of geographers and geologists to assume that they must live apart; and that geographical societies and geological societies have no work in common; but the modern understanding of geography corrects this older view, and leads the two sciences and the two groups of societies, in which the two sciences are cultivated, into more and more intimate relations. Hence I hold it to be entirely appropriate to introduce considerations gained from a study of the past in a lecture concerning the forms of the present.

There is an even deeper and stronger reason for the interplay of geological and geographical problems. It is the effort of many geographers to-day to give explanatory, rather than empirical, descriptions of land forms; that is, to treat each land form in view of its origin; to present it as the product of some process working on some structure; and in order to do this systematically, it has been

proposed that every land form should be described in terms of the structure of the mass of which it is the surface; of the process or processes by which the mass is carved; and of the stage reached by the carving processes, in view of the whole series of stages from the beginning when the land mass was first uplifted and exposed to carving, until the end when it shall be worn down to a featureless lowland. Evidently a systematic scheme of this sort cannot hope to find acceptance, until it is shown that the processes of erosion may really run all through the cycle of their changes, producing a systematic sequence of changing forms that ends in a plain of erosion; and it is directly here that the occurrence of the deeply buried, ancient surface of completed erosion in the canyon walls is so serviceable to geographers. The ancient surface gives them confidence that the scheme of the cycle of erosion is not merely a fanciful conception, but that it has had reality. It demands the former occurrence of a whole procession of changing forms, from the initial form produced by uplift to the ultimate form produced by down-wearing. It gives warrant not merely to the acceptance of the scheme of the cycle of erosion as a well-substantiated theory, but even more to its adoption as a practical aid in the systematic description of existing land forms; for all land forms that we see must be now on their way through the current cycles of erosion on which they have entered. The fossil plain of ancient origin, long preserved by burial and now seen in section in the canyon walls, is therefore immediately pertinent to our description of the existing canyon as a young canyon; and the more clearly one conceives the origin of the buried plain, after reconstructing its several sections into a widely extended surface, the more fully will one feel justified in describing the canyon as a young valley.

Repetition is a good principle in teaching; and in this respect the canyon is a good teacher; for no sooner have we learned the lesson that the foundation crystallines represent two long chapters of earth history—one occupied in the making of their total mass, the other spent in wearing away a great part of it—than the lesson is repeated with just enough identity to make it convincing, and enough variety to make it interesting. The heavy strata of the wedge series, resting unconformably on the truncated structures of the crystalline schists, and more than two miles in thickness, must have required an enormously long third chapter of earth history in their making; for they represent the extensive erosion of some neighbouring land mass, and the bringing of its materials, grain by grain, from their source to their place of deposition. Then, after deposition, came the

tilting of the compound mass, and the erosion of its upper part, so as to truncate both the wedge series and its crystalline foundation in an almost level surface; and this destructive work must, in its turn, have required an enormously long fourth chapter of ancient time, compared to which the erosion of the canyon is but a beginning.

One may not in a lecture delay the attention of the hearers by attempting to give a realistic imitation of these long enduring processes of deposition and degradation; for the lecture would run through its brief course before any significant shifting of the sands in the geological hour-glass had taken place. But it is desirable that those of the audience who wish to approach nearer to a comprehension of the time-measures that are involved in cycles of deposition and of degradation, should take occasion, when they are out doors on some sloping hillside, to reflect a while upon the extreme slowness of the process involved; that they should strive to imagine the wearing down of the hill before them by the very processes of weathering that are silently at work before their eyes, until the hill shall be reduced to a lowland plain. At the same time, effort must be made to visualize the changes of form and their orderly sequence with the passage of time. Only after thoughtful meditation can one make a good step towards realizing the periods of time and the changes of form with which we are here concerned; only then can one begin to appreciate the geographical applications of the geological history recorded in the canyon walls by the even line of unconformity between the wedge series and the foundation crystallines, and between both of these formations and the overlying plateau series.

Thus the series of past events, accomplished before the canyon was begun, stretches out in a long procession; and the visitor, who at first thought that the erosion of the canyon must have occupied much of the history of the earth, begins to gain some better comprehension of the long vistas of early ages, all to be passed through before the canyon was thought of.

The unconformable deposition of the horizontal strata of the plateau series did not begin until the underlying compound mass was evenly truncated. The change then made from erosion in the fourth chapter to deposition in the fifth must be interpreted as due to a submergence of the worn-down region, so that it became the seat of deposition of the plateau series of strata, whose materials were furnished by erosion in some other region. Thus a fifth chapter of time is indicated, again very long in comparison with the time required for the erosion of the young canyon. This chapter in-

cluded the geological ages from Cambrian to Carboniferous, the first of which is represented in the lower members of the plateau series, and the last in the capping members which form the plateau surface of to-day. And now the visitor, perhaps becoming impatient at the long delay of these preparatory chapters, and wishing to hear something about the canyon, thinks that the opening of the next chapter will witness the uplift of the three-fold plateau mass, and the beginning of canyon erosion; but this is far from being the case. We must not attempt to hurry the events of the earth's history. An excursion northward across the plateau will bring us to a great group of retreating escarpments, formed on the outcropping edges of a heavy series of strata, some 5,000 feet thick, which overlie the plateau series; and these escarpments demand the occurrence of a sixth and a seventh chapter after the making of the plateau series and before the beginning of the canyon chapter; a sixth chapter for the deposition of the overlying strata on the whole of the plateau region; and a seventh chapter for their removal over thousands of square miles, exposing the present plateau surface as a lowland; and assuredly both of these chapters were long in comparison to the time required for the excavation of the narrow canyon. The seventh chapter may have begun with the erosion of a young canyon as long and deep and narrow as the present canyon; but it continued until the young canyon was widened to a broad valley, and until the broad valley expanded to an extensive lowland. Only then was the lowland uplifted to the altitude of the present plateau, and the erosion of the present canyon begun.

It is fatiguing, this long perspective of past time. The mind fails to grasp its duration, even if patient enough to enumerate its subdivisions. Yet an effort towards a comprehension of the geological history of the plateau region is profitable for the geographer, for only after some comprehension of this history, is he really prepared to enter into sympathy with the features of the land and the processes of land sculpture, and to regard the canyon as Mother Earth regards it. It is highly profitable to stand on the rim of the plateau and to peer into the depths of the canyon; to identify, as one may so easily, the several rock masses which, in their making and unmaking, represent the first five of the seven chapters of past history; it is better still to rove northward over the plateaus and see the great escarpments, stubbornly standing forth, yet inevitably retreating under the unceasing attack of the weather, as representatives of the sixth and seventh chapters; and then to return to the canyon and look into it once more, with deeper appreciation. It is

wholesome now to recall the impressions suggested by the first sight of the canyon ; and to compare them with the broader understanding that has been gained by the thoughtful examination of the canyon walls.

The canyon teaches its lessons impressively because it is immense ; it teaches them effectively because the great facts on which they are based are presented in grand simplicity. No one can learn these lessons without reaching a feeling of exaltation ; no one can then fail to conclude that this earth which we inhabit is a working earth. If it be the province of the geographer to describe its present features, he must become something of a geologist before he can describe them sympathetically. It is really a moving picture that we see in a landscape ; if it appears fixed, that is the fault of our too hurried, too thoughtless glance.

The hills are shadows and they flow  
From form to form and nothing stands,  
They melt like mist ; the solid lands  
Like clouds, they shape themselves and go.

Geographers must not content themselves with unappreciative empirical descriptions of land forms as fixed and finished, and leave to geologists and poets the fuller presentation of the greater truths concerning physiographic evolution. But geographers must have a care, so long as they are presenting explanatory geographical descriptions, to place emphasis on the forms produced by the processes, and not on the processes that have produced the forms. If in this lecture the attention of the hearers has been diverted from the present to the past, let it now come back to the present, and, with the first picture of the canyon again on the screen, let us recognize that all the accounts of the past as inferred from the records of the canyon walls have been introduced solely in order to give good warrant for describing the canyon as a young valley ; we may call it a precocious young valley, if it is desired to emphasize its depth, but we must see that it is as yet far from being venerable.